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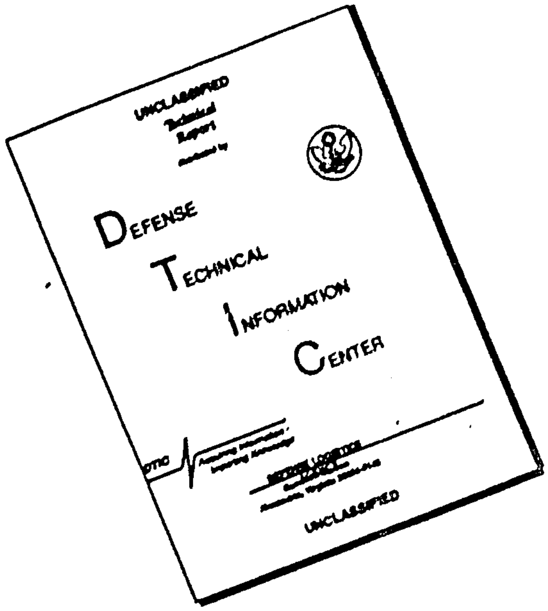

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NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN

THE PLANING CHARACTERISTICS OF A V-SHAPED PRISMATIC SURFACE WITH 70 DEGREES DEAD RISE

by

James D. Pope, Ltjg., USN

~~HYDROMECHANICS~~

AERODYNAMICS

STRUCTURAL MECHANICS

APPLIED MATHEMATICS

HYDROMECHANICS LABORATORY
RESEARCH AND DEVELOPMENT REPORT

December 1958 Report 1285

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NOTATION

b	Beam of planing surface, ft
C_R	Resistance coefficient, R/wb^3
C_V	Speed coefficient or Froude number, $V/\sqrt{gb}$
C_Δ	Load coefficient or beam loading, Δ/wb^3
C_{D_b}	Drag coefficient based on beam, $\dfrac{R}{\frac{\rho}{2}V^2b^2} = \dfrac{2C_R}{C_V{}^2}$
C_{D_S}	Drag coefficient based on principal wetted area, $\dfrac{R}{\frac{\rho}{2}V^2S} = \dfrac{C_{D_b}}{\frac{l_m}{b}}$
C_{L_b}	Lift coefficient based on beam, $\dfrac{\Delta}{\frac{\rho}{2}V^2b^2} = \dfrac{2C_\Delta}{C_V{}^2}$
C_{L_S}	Lift coefficient based on principal wetted area, $\dfrac{\Delta}{\frac{\rho}{2}V^2S} = \dfrac{C_{L_b}}{\frac{l_m}{b}}$
d	Draft, ft
F	Friction, parallel to planing surface, lb
g	Acceleration due to gravity, 32.155 ft/sec^2
l_c	Chine wetted length, ft

l_k	Keel wetted length, ft
l_m	Mean wetted length, $\frac{l_c + l_k}{2}$, ft
l_p	Center-of-pressure location (measured along keel forward of trailing edge), $\frac{M}{\Delta \cos \tau + R \sin \tau}$, ft
M	Trimming moment about trailing edge of model at keel, ft-lb
R	Horizontal resistance, lb
S	Principal wetted area (bounded by trailing edge, chines, and heavy spray line) projected on plane parallel to keel, $l_m b$, sq ft
S_f	Actual wetted area aft of stagnation line, sq ft
V	Horizontal velocity, ft/sec
V_m	Mean velocity over planing surface, ft/sec
w	Specific weight of water, lb/cu ft
β	Angle of dead rise, deg
Δ	Vertical load, lb
ν	Kinematic viscosity, ft^2/ sec
ρ	Mass density of water, slugs/cu ft
τ	Trim (angle between keel and horizontal), deg

ABSTRACT

This report is one of a series on the experimental investigation of the planing characteristics of a series of related prismatic surfaces.

The principal planing characteristics have been obtained for a V-shaped prismatic surface having an angle of dead rise of 70 degrees. Wetted lengths, resistance, and center-of-pressure location were determined at speed coefficients from 2.17 to 36.85, and trims up to 30 degrees. Keel-wetted-length—beam ratios were extended to approximately 8.0 in all cases where excessive loads or excessive spray conditions were not encountered.

The data obtained indicate that the important planing characteristics are independent of speed and load for a given trim and are dependent primarily upon lift coefficient. The difference between keel wetted length and chine wetted length is constant for a given trim angle, and the variation of this difference with trim has the same general trend as indicated by theory. The drag data indicate that the friction drag decreases with increase in trim.

INTRODUCTION

The National Aeronautics and Space Administration (formerly the National Advisory Committee for Aeronautics) and the David Taylor Model Basin have undertaken an experimental investigation of a series of related prismatic planing surfaces. The principal purpose of this investigation is to extend the available data to high speeds, high trims, and long wetted lengths. The results of tests of surfaces having angles of dead rise of 0, 20, 40, 50, and -10 degrees have already been published (References 1 to 7).[1]

The present report gives the results obtained with a prismatic surface having an angle of dead rise of 70 degrees. The principal planing characteristics were determined for speed coefficients up to approximately 20.0, beam loadings up to 36.85, wetted lengths up to 8 beams, and trims up to 30 degrees. The characteristics determined were wetted length, resistance, and center-of-pressure location for suitable combinations of speed, load, and trim.

DESCRIPTION OF MODEL

The model is made of brass, has a beam of 4 inches, and an angle of dead rise of 70 degrees. The length, exclusive of the sheet-metal fairing at the bow, is 36 inches. The tolerances and the finish of the model are the same as those described in References 6 and 7. As in the case of the 50-degree dead rise model described in Reference 6, the side of the model above the chine makes an angle of 90 degrees with the bottom.

APPARATUS AND PROCEDURES

General

The test program was conducted in the high-speed

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1 References are listed on pages 6 and 7.

basin on Carriage 3. A brief description of the basin and carriage is given in Reference 8. The apparatus for towing the model and the instrumentation for measuring the lift, drag, and trimming moment are of the type described in Reference 9. Drawings of the towing gear and similar models are presented in References 6 and 7.

Wetted Length and Area

The wetted areas were determined from underwater photographs in the manner described in Reference 6. In addition, visual readings of the chine wetted lengths were recorded with the aid of a scale marked on the side of the model.

The wetted lengths were measured from the trailing edge to the intersection of the keel and chines with the heavy spray line. This spray line was essentially straight from keel to chine throughout the range of the tests, and the mean wetted length was therefore the average of the keel and chine wetted lengths.

Draft

Reference 10 specified that draft should be calculated from the trim and the precisely determined wetted length at the keel. Accordingly, draft was not measured directly, but should be calculated from the relationship $d = l_k \sin \tau$. In Reference 5, some measured values of draft for V-shaped prismatic surfaces having angles of dead rise of 20 degrees and 40 degrees are compared with the values computed from the keel wetted length. At the high trims, the measured values of draft are slightly lower than the calculated values. This difference is evidently caused by some pile-up of water at the keels of the models. It is assumed that a similar effect exists for the 70-degree dead rise surface and that the calculated values of draft will therefore be slightly high at the high trims.

A careful survey of the water surface in the test area indicated no appreciable gradient in height due to the towing carriage or wind screen.

Aerodynamic Tares

The aerodynamic forces on the model and towing gear were held to a minimum by the use of a wind-screen housing the test section of the towing carriage. This wind-screen was constructed of 1/16-inch aluminum, and was similar in shape to that described in Reference 2.

The residual windage tares were determined by making a series of runs at various speeds with the model just clearing the surface of the water. The tares for drag, load, and moment were found to be negligible over the speed range.

Precision

The quantities measured are believed to be accurate within the following limits:

Load, lb	±0.15
Resistance, lb	±0.15
Trimming moment, ft-lb	±0.50
Wetted length, in.	±0.25
Trim, deg	±0.10
Speed, ft/sec	±0.20

RESULTS AND DISCUSSION

General

The experimental data obtained for all planing conditions where the chines of the model were wet, are presented in Table 1. The corresponding data for the dry chine condition have been omitted. Also, following the general practice of this program, the light-load low-speed conditions, where the buoyancy exceeded 20 percent of the total load, were considered nonplaning and are not included in this report. For these reasons, no data for 2-, 4-, and 6-degree trim angles appear in Table 1.

The load, resistance, speed, wetted lengths, and center of pressure are expressed as conventional non-dimensional hydrodynamic coefficients based on beam. The lift and drag coefficients are expressed both in terms of the square of the beam and in terms of the principal wetted area.

Plots of the data are presented in Figures 1 to 6. When plotted against C_{L_b}, the experimental data generally fall along a single curve for each trim. These trends are the same as those found for the surfaces having dead rise angles from -10 to 50 degrees.

Wetted Length

The variation of the mean-wetted-length — beam ratio l_m/b with C_{L_b} is shown in Figure 1. The relation between keel-wetted-length — beam ratio l_k/b and the chine-wetted-length— beam ratio l_c/b is shown in Figure 2. The difference between the chine wetted length and the keel wetted length is constant for a given trim. By definition, a similar variation necessarily holds for the relation between the mean wetted length and the chine wetted length.

The variation of the difference between the keel and chine wetted lengths with trim is shown in Figure 3. The variation predicted by the two-dimensional theory of Wagner, as applied in Reference 11, is also shown. The experimental curve is in reasonable agreement with the theoretical curve, although its absolute values fall somewhat below those of the theoretical curve.

Center of Pressure

The center-of-pressure location l_p is defined as the distance from the trailing edge to the intersection of the resultant hydrodynamic force vector with the keel of the model. A plot of center-of-pressure location in beams against C_{L_b} is presented in Figure 4.

Figure 5 presents plots of l_p/b against l_m/b for trim angles of 18, 24, and 30 degrees. The data were insufficient to allow similar plots of the 9-and 12-degree trims.

Resistance

The resistance data are presented in Figure 6 as a plot of drag coefficient C_{D_b} against lift coefficient C_{L_b}. The solid lines faired through the data represent the total drag whereas the dashed lines, defined by $C_{L_b} \tan \tau$, represent the induced drag. The difference between the solid and dashed lines represents the friction drag. It can be seen that the friction drag decreases with increase in trim angle.

CONCLUSIONS

The results obtained from an experimental investigation of a V-shaped planing surface having an angle of dead rise of 70 degrees indicate that, during steady-state planing, the important planing characteristics are independent of speed and load for a given trim and are dependent only on lift coefficient. The difference between keel wetted length and chine wetted length is constant for a given trim angle, and the variation of this difference with trim is shown to be in fair agreement with theory. The drag data indicate that the friction drag decreases with increase in trim.

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TABLE 1

Experimental Data Obtained for 70-deg Dead Rise Planing Surface

Average kinematic viscosity = 1.076×10^{-5} ft²/sec;
average specific weight of basin water = 62.27 lb/ft³

τ deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_s}	C_{L_s}
9	6.504	16.993	6.721	1.740	4.400	7.060	3.189	0.0450	0.0466	0.0102	0.0106
9	10.840	16.425	8.000	1.950	4.595	7.240	3.715	0.0804	0.0593	0.0175	0.0129
12	4.336	13.887	3.577	0.840	2.810	4.780	2.315	0.0450	0.0371	0.0160	0.0132
12	6.504	17.024	5.420	1.000	2.955	4.910	2.310	0.0449	0.0374	0.0152	0.0127
12	10.840	16.467	7.762	2.690	4.595	6.500	2.852	0.0800	0.0572	0.0174	0.0125
12	19.510	17.643	13.007	4.710	6.615	8.520	3.799	0.1254	0.0836	0.0190	0.0126
18	2.168	9.822	1.192	0.240	1.470	2.700	1.037	0.0449	0.0247	0.0306	0.0168
18	4.336	13.877	2.732	0.340	1.580	2.820	1.199	0.0450	0.0284	0.0285	0.0180
18	6.504	10.199	3.569	2.180	3.400	4.620	2.084	0.1251	0.0686	0.0368	0.0202
18	6.504	12.732	3.881	1.260	2.492	3.725	1.637	0.0802	0.0478	0.0322	0.0192
18	6.504	17.003	4.141	0.370	1.608	2.845	1.329	0.0450	0.0286	0.0280	0.0178
18	10.840	13.165	6.244	2.425	3.662	4.900	2.178	0.1251	0.0721	0.0342	0.0197
18	10.840	16.415	6.604	1.450	2.680	3.910	1.723	0.0805	0.0490	0.0300	0.0183
18	19.510	14.733	10.709	3.850	5.040	6.230	2.796	0.1798	0.0987	0.0357	0.0196
18	36.853	17.302	20.070	5.210	6.425	7.640	3.645	0.2462	0.1341	0.0383	0.0209
24	6.504	10.235	3.816	1.730	2.570	3.410	1.399	0.1242	0.0729	0.0483	0.0283
24	10.840	9.404	5.594	3.110	3.940	4.770	2.115	0.2451	0.1265	0.0622	0.0321
24	10.840	13.139	6.547	1.660	2.515	3.370	1.548	0.1256	0.0759	0.0499	0.0302
24	10.840	16.436	6.569	0.950	1.791	2.630	1.147	0.0803	0.0486	0.0448	0.0272
24	10.839	13.186	6.677	1.995	2.855	3.715	1.583	0.1247	0.0768	0.0437	0.0269
24	10.839	16.436	6.590	1.030	1.870	2.710	1.217	0.0843	0.0488	0.0429	0.0261
24	19.510	12.618	11.468	3.670	4.485	5.300	2.441	0.2450	0.1441	0.0546	0.0321
24	19.510	14.682	11.858	2.690	3.505	4.320	2.014	0.1810	0.1100	0.0516	0.0314
24	19.510	17.581	12.335	1.760	2.615	3.470	1.627	0.1262	0.0798	0.0483	0.0305
24	36.853	12.154	20.811	7.160	7.890	8.620	4.086	0.4990	0.2810	0.0633	0.0358
24	36.853	13.464	20.898	6.080	6.860	7.640	3.577	0.4066	0.2306	0.0593	0.0336
24	36.853	15.167	21.635	4.890	5.710	6.530	3.075	0.3204	0.1881	0.0561	0.0329
24	36.853	17.364	22.112	3.820	4.650	5.480	2.570	0.2445	0.1467	0.0526	0.0315

TABLE 1 (Concluded)

τ deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_s}	C_{D_s}
30	4.336	13.867	3.122	0.225	0.802	1.380	0.624	0.0451	0.0325	0.0562	0.0405
30	6.504	10.204	4.423	1.450	2.045	2.640	1.202	0.1249	0.0850	0.0611	0.0415
30	6.504	12.742	4.510	0.840	1.455	2.070	0.954	0.0801	0.0556	0.0551	0.0382
30	6.504	17.013	4.726	0.260	0.876	1.490	0.729	0.0449	0.0327	0.0513	0.0373
30	10.839	9.399	6.915	2.760	3.320	3.880	1.790	0.2454	0.1566	0.0739	0.0472
30	10.839	10.978	7.219	2.110	2.685	3.260	1.475	0.1799	0.1198	0.0670	0.0446
30	10.839	13.082	7.522	1.430	2.000	2.570	1.293	0.1267	0.0879	0.0633	0.0440
30	10.839	13.166	7.197	1.430	2.035	2.640	1.180	0.1247	0.0828	0.0613	0.0407
30	10.839	16.456	7.544	0.810	1.420	2.030	0.919	0.0800	0.0557	0.0564	0.0392
30	10.839	16.456	7.826	0.840	1.435	2.030	0.999	0.0800	0.0578	0.0558	0.0403
30	19.510	10.847	13.224	3.700	4.250	4.800	2.334	0.3256	0.2207	0.0766	0.0519
30	19.510	11.060	12.898	3.695	4.278	4.860	2.274	0.3190	0.2109	0.0746	0.0493
30	19.510	12.608	12.985	2.930	3.500	4.070	1.898	0.2455	0.1634	0.0701	0.0467
30	19.510	12.608	13.397	2.960	3.530	4.100	1.992	0.2455	0.1686	0.0695	0.0478
30	19.510	14.671	13.397	2.190	2.770	3.350	1.588	0.1813	0.1245	0.0654	0.0449
30	19.510	14.682	13.527	2.200	2.765	3.330	1.607	0.1810	0.1255	0.0655	0.0454
30	19.510	17.364	13.657	1.460	2.048	2.635	1.270	0.1294	0.0906	0.0632	0.0442
30	19.510	17.643	13.419	1.450	2.058	2.665	1.245	0.1254	0.0862	0.0609	0.0419
30	36.853	12.102	24.592	5.720	6.270	6.820	3.261	0.5032	0.3358	0.0803	0.0536
30	36.853	12.154	24.592	5.790	6.350	6.910	3.269	0.4990	0.3330	0.0786	0.0524
30	36.853	13.464	24.496	4.800	5.365	5.930	2.806	0.4066	0.2703	0.0758	0.0504
30	36.853	13.485	24.800	4.840	5.415	5.990	2.841	0.4053	0.2728	0.0749	0.0504
30	36.853	15.074	25.450	3.940	4.530	5.120	2.452	0.3244	0.2240	0.0716	0.0495
30	36.853	15.156	25.060	3.920	4.490	5.060	2.414	0.3209	0.2182	0.0715	0.0486
30	36.853	17.251	25.624	3.095	3.672	4.250	2.034	0.2477	0.1722	0.0674	0.0469
30	36.853	17.333	25.298	3.080	3.660	4.240	1.994	0.2453	0.1684	0.0670	0.0460

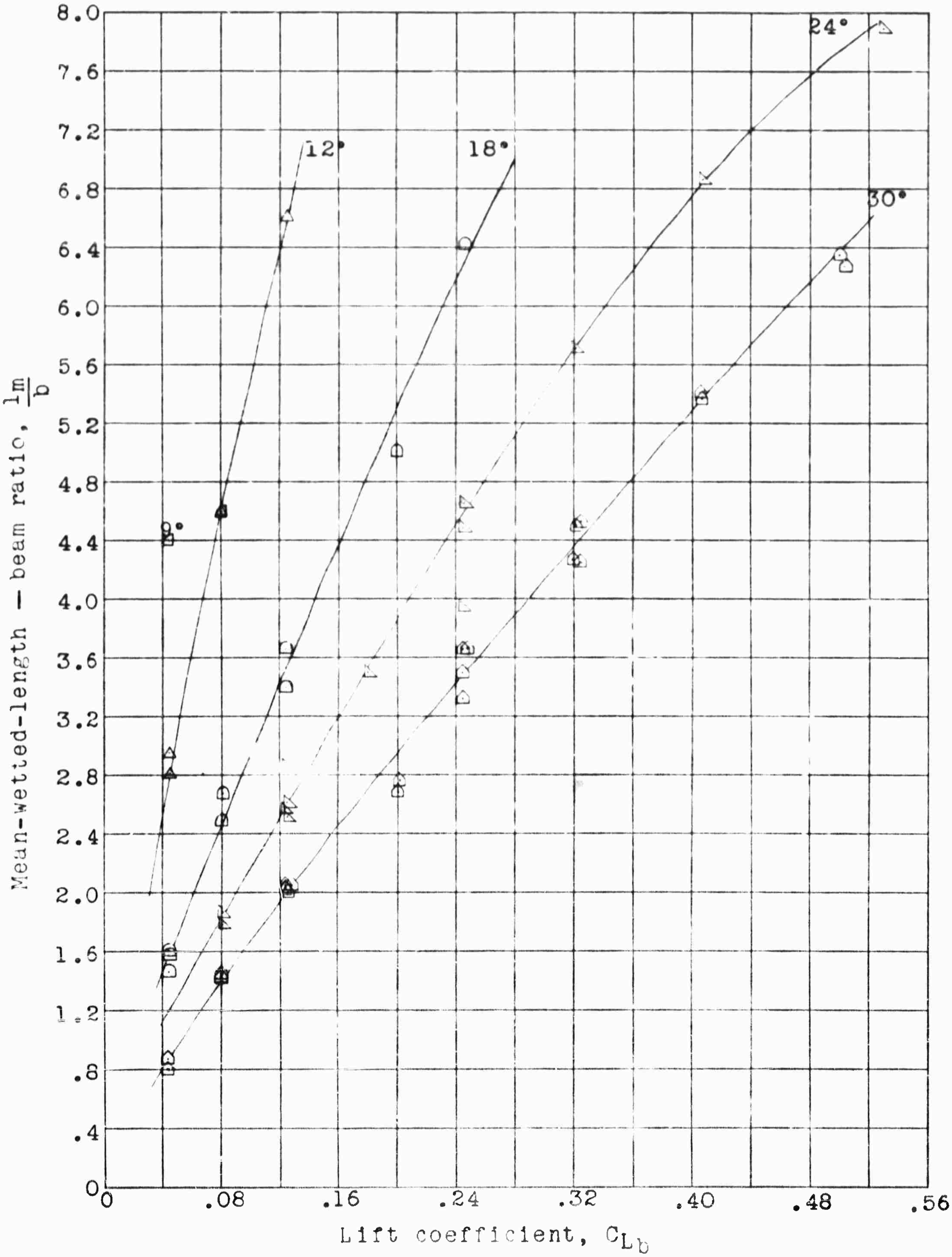

Figure 1 - Variation of Mean-Wetted-Length -Beam Ratio l_m/b with Lift Coefficient C_{L_b}

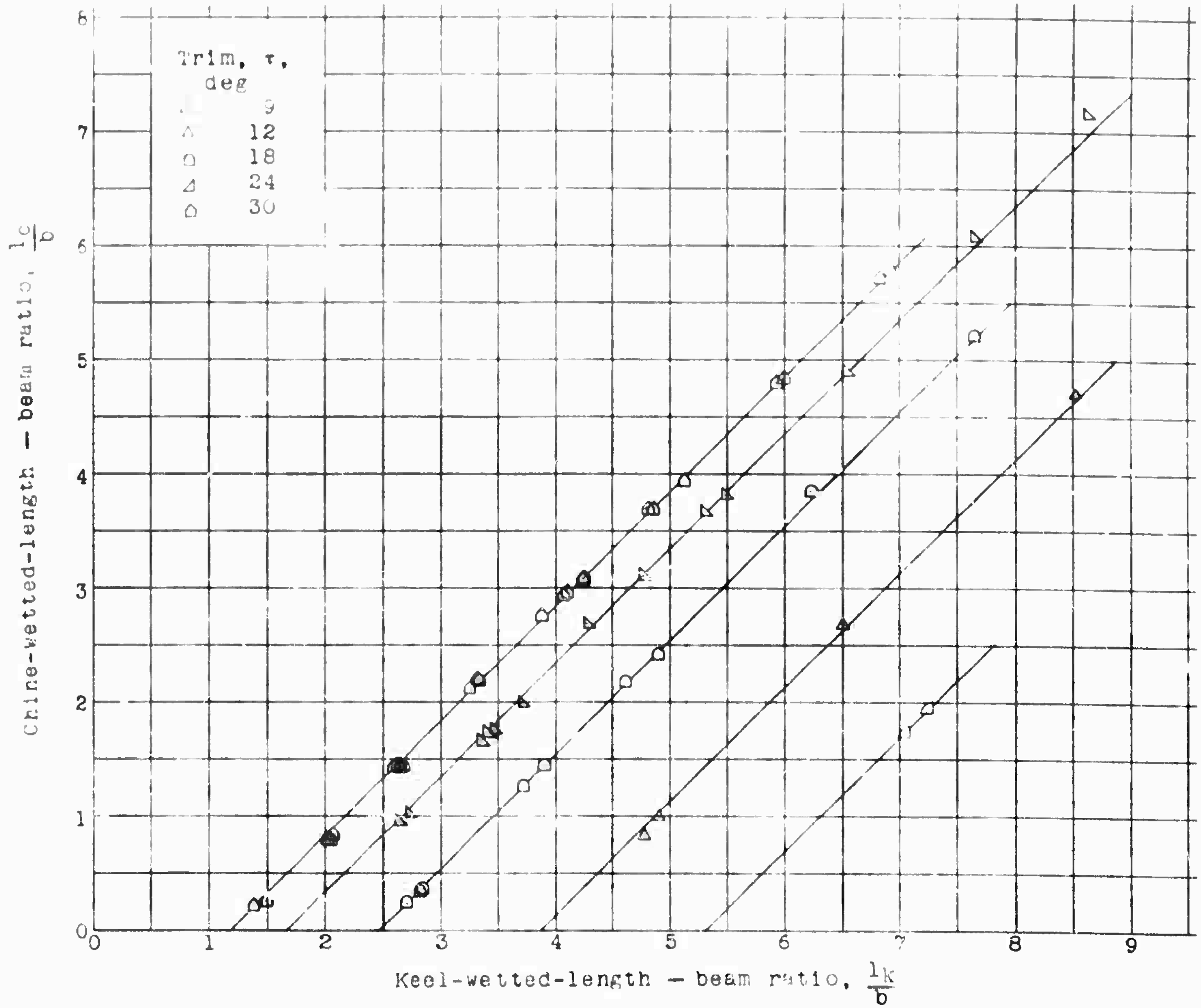

Figure 2 - Variation of Chine-Wetted-Length—Beam Ratio With Keel-Wetted-Length—Beam Ratio

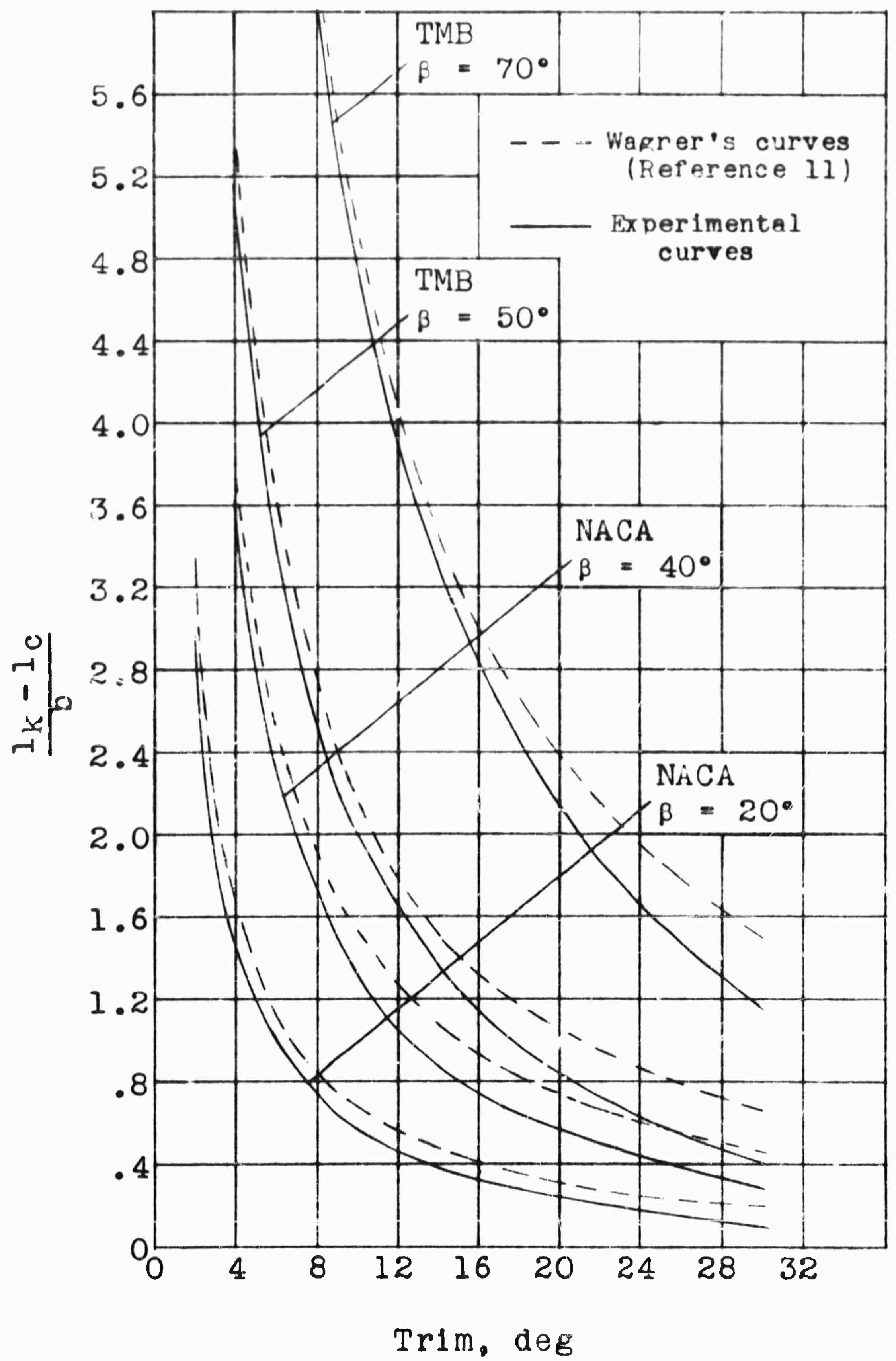

Figure 3 - Variation of $\frac{l_k - l_c}{b}$ with Trim

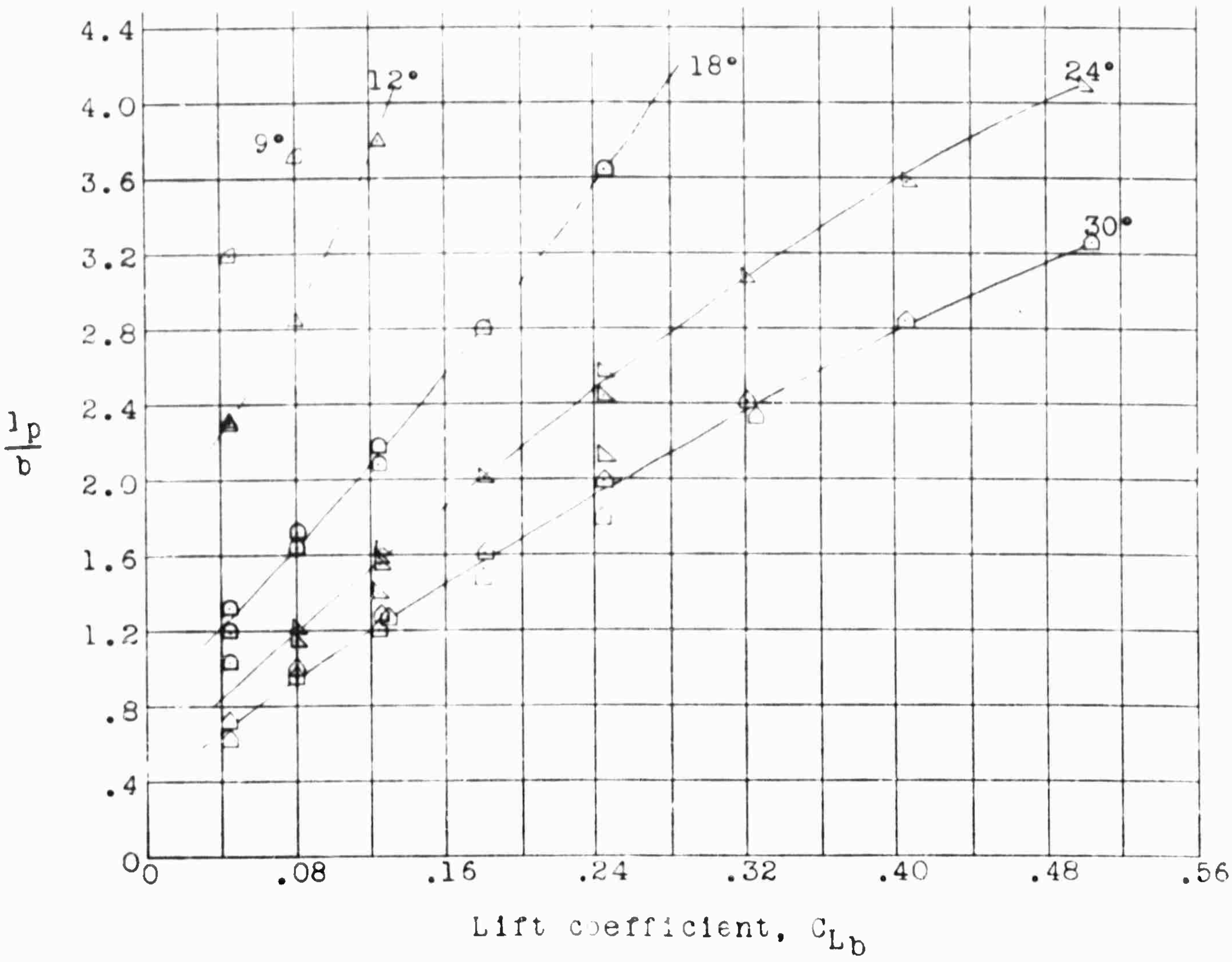

Figure 4 - Variation of Nondimensional Center-of-Pressure Location l_p/b with Lift Coefficient C_{L_b}

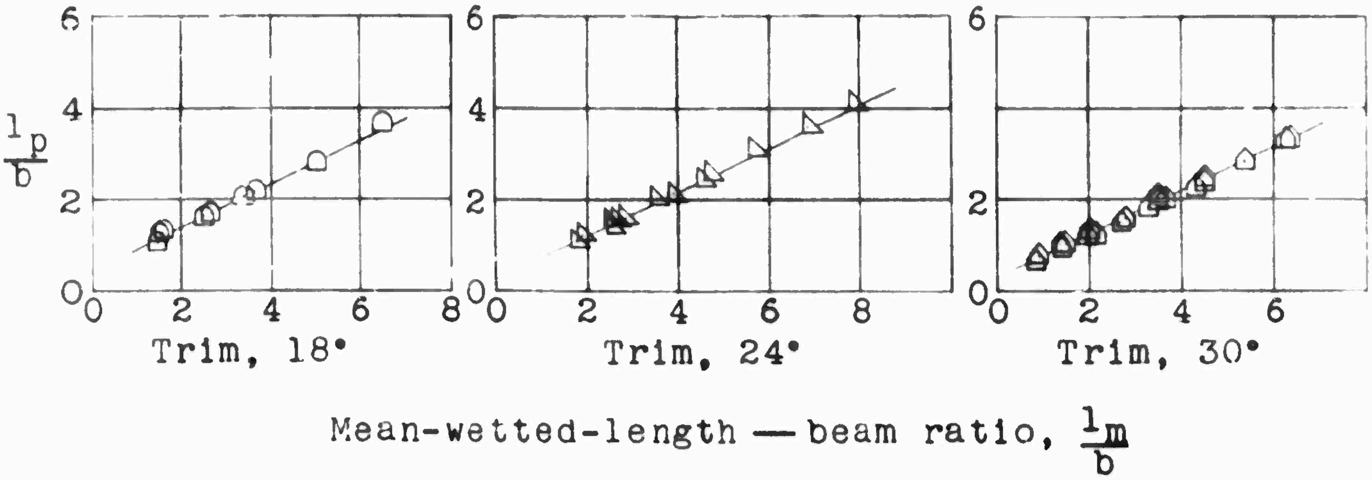

Figure 5 - Variation of l_p/b with l_m/b

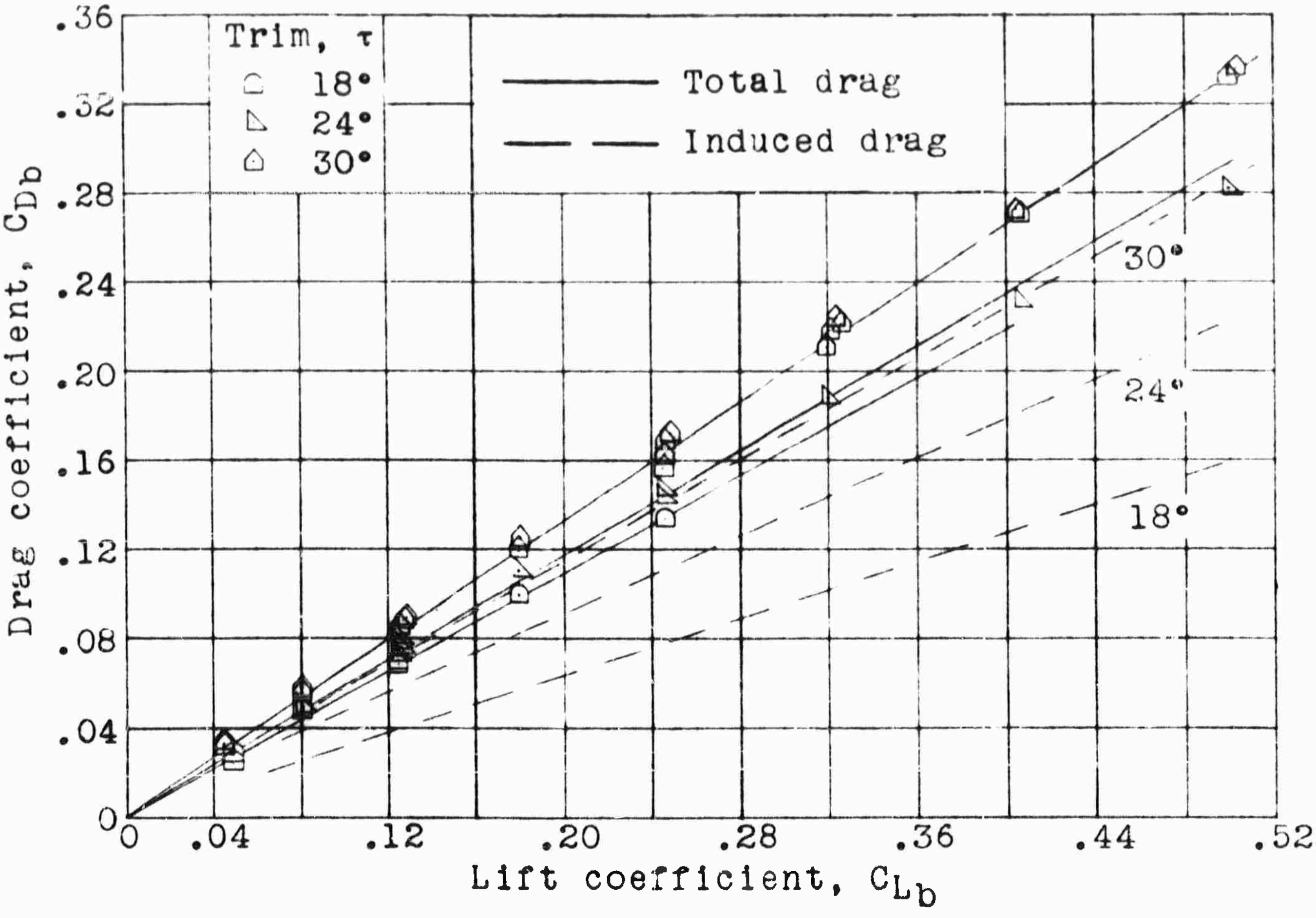

Figure 6 - Variation of Drag Coefficient C_{D_b} with Lift Coefficient C_{L_b}

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1	Republic Aviation Corp, Farmingdale, L.I;, N.Y. Attn: Mr. A.A. Kartveli
1	Sparkman & Stephens, Inc., New York, N.Y.
1	Des Supt, Philadelphia Naval Shipyard
1	Electric Boat Co., Groton, Conn.
1	Ventnor Boat Corp, Atlantic City, N. J.